REMARKS

The subject invention relates to optically pumped semiconductor (OPS) lasers. In these devices, a semiconductor chip is formed with a multi-quantum well gain medium (12) and an attached resonator mirror (14). An external mirror (not shown in the drawings) defines the resonator. The surface of the gain medium is optically pumped to generate laser light.

Continuing efforts are being made to increase the output power of these OPS lasers. As the power levels increase, it becomes more important to remove heat from the gain structure. In the past, it has been known to bond a copper heat sink to the OPS chip to remove heat. To improve heat flow, it has also been known to adhesively bond a diamond heat spreader between the OPS chip and the copper heat sink. Adhesive or solder bonding is simple and inexpensive but has certain problems. First, the solder is not particularly thermally conductive and thus restricts the heat flow from the chip to the heat sink. Further, when heated, the solder can produce stresses between the bonded elements that can alter optical properties and even result in cracks in the chip.

In order to overcome this problem, applicants use an alternate bonding approach. More specifically, applicants directly connect the diamond heat conducting element to the OPS chip using "contact bonding." As set forth in the specification at page 5, line 4, the term contact bonding is intended to define a bond that is "formed without a physical adhesive between the bonded members." This type of bond requires that the elements be very flat and very clean. The two surfaces are then brought into pressure contact. Preferably, the assembled structure is then annealed at elevated temperatures, between 100 – 350 degrees centigrade (see specification at page 10, line 13 for more details).

In the Office Action, the Examiner rejected claims 1 to 6, 10, 11 and 13 as being obvious based on the patent to Salokatve (6,327,293) in view of Lim (6,569,380). As noted by the Examiner, Salokatve, which is commonly owned with this application, discloses an optically pumped semiconductor (OPS) laser having semiconductor chip including gain layers 16 and Bragg mirror 14. The OPS chip is bonded to a heat sink 32 via a conventional bonding layer 31. Salokatve fails to disclose or suggest the claimed arrangement where the heat sink is contact bonded to the OPS chip without adhesive.

The Examiner cites the Lim patent as teaching bonding without adhesive and argues that it would be obvious to modify Salokatve with the teachings of Lim to arrive at the claimed invention. Applicants traverse this rejection.

It is true that Lim discusses the concept of bonding without adhesive. However, a closer review of Lim reveals that his teachings are completely different and not at all applicable to an OPS laser. To understand Lim, it is convenient to start with his Figure 2 which shows an "enclosure 34" for attachment to a circuit board 50. The enclosure supports a semiconductor integrated circuit chip 30. This chip is bonded, in normal fashion, to the enclosure 34 (specification, column 5, line 45). Figure 2 also shows a heat sink 42 which is connected to the enclosure 34. It is the connection between the heat sink and the enclosure that defines Lim's bond "without adhesive."

In accordance with Lim, the enclosure and heat sink elements are formed from powdered metal to which lubricants and binders are added. The powdered feedstock is then injection molded into the parts to produce a structure of the type illustrated in Figure 4. At this stage, the binder is removed by heating or by a solvent. The powdered metal parts are then placed into a sintering furnace which heats the parts to an extremely high temperature - between 1000 and 1600 degrees centigrade (specification, column 5, line 19). This high temperature "sinters" the powders causing the two parts to be fused without an adhesive. As noted above, the semiconductor chip is then bonded, in normal fashion, onto the enclosure.

It is respectfully submitted that one skilled in the art would never consider the teachings of Lim to be relevant to Salokatve. First, the approach in Lim is simply not "contact bonding" as it is defined in the subject application and claims. Lim teaches connecting parts by sintering. Sintering is suitable for connecting powdered metal parts. It could not be applied to bonding a semiconductor structure to a heat sink. As noted in the specification, the OPS gain medium of the subject invention is fabricated from epitaxially growth techniques. Although the semiconductor layers can withstand the elevated temperatures of a contact bonding technique (100 to 350 degrees centigrade), it would never survive at sintering temperatures in excess of 1000 degrees centigrade. In addition, it should be noted that the approach in Lim is merely for connecting a support structure to a heat sink. With regard to the semiconductor chip, Lim teaches the known prior art, simply bonding the chip to the enclosure. It should be noted that

applicants have amended the claims to more clearly recite that the gain structure is formed from a semiconductor material.

It is respectfully submitted that Lim, which teaches an extremely high temperature sintering technique for bonding powdered metal materials, fails to overcome the deficiencies of Salokatve in teaching or rendering obvious applicants' invention.

In the Office Action, the Examiner cited the patent to Raymond (6,393,038) for its teaching of a second heat conducting member and a copper heat sink. Raymond does teach the use of a copper heat sink but the copper heat sink appears to be the only heat conducting member disclosed in Raymond. More importantly, Raymond only discloses "mounting" the OPS chip on the heat sink. There is no teaching in Raymond that this mounting should be a contact bond created by pressure without an adhesive. Accordingly, Raymond fails to overcome the deficiencies of the primary references in rendering obvious applicants' invention.

In the Office Action, the Examiner cited the patent to Zayhowski (5,386,427) for its teaching of a sapphire heat conducting element. Zayhowski relates to a thermally controlled lens that is cooled by a heat sink. Zayhowski merely states that the heat sink is "thermally coupled" to the lens. There is no teaching in Zayhowski that the heat sink should be connected to the lens by a contact bond created by pressure without an adhesive. Accordingly, Zayhowski fails to overcome the deficiencies of the primary references in rendering obvious applicants' invention.

In the Office Action, the Examiner cited the patent to Pinneo (6,919,525) for its teaching of a CVD diamond heat spreader. Pinneo is directed towards semiconductor packaging and discloses positioning a diamond heat spreader between a microprocessor and the package enclosure, which in turn, is connected to a heat sink. Pinneo teaches that the diamond heat spreader can be attached to the microprocessor by brazing, adhesive or solder. In the Figure 5 embodiment of Pinneo, thin sheets of flexible graphite are interposed between the microprocessor and the heat spreader. In order to avoid the use of adhesive bonding and thereby reduce mechanical shear forces, the assembly of Figure 5 is held together with a spring clip. Pinneo fails to teach a contact bond created by pressure without adhesives. Accordingly, Pinneo fails to overcome the deficiencies of the primary references in rendering obvious applicants' invention.

Based on the above, it is respectfully submitted that all of the independent claims define patentable subject matter and allowance thereof, along with the claims depending therefrom is respectfully requested.

Respectfully submitted,

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